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RESEARCH ON THE FLAMMABILITY CHARACTERISTICS OF AIRCRAFT HYDRAULIC FLUIDS

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UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

MAY 1957

WRIGHT AIR DEVELOPMENT CENTER

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WRIGHT AIR DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

FOREWORD

This report was prepared by the Branch of Gas Explosions, Division of Explosives Technology of the U. S. Bureau of Mines under USAF Contract No. AF 18(600)-151. The contract was initiated under Project No. 3044, "Aviation Lubricants", Task No. 73314, "Lubricants". It was administered under the direction of the Materials Laboratory, Directorate of Research, Wright Air Development Center, with Mr. Howard D. C. Hill acting as project engineer.

Drs. Robert W. Van Dolah and Glenn H. Damon were the administrators for the U. S. Bureau of Mines and Dr. M. G. Zabetakis, Messrs. A. L. Furno and J. J. Miller, and Miss Marilyn Hartmann conducted all the experimental work for this project at the U. S. Bureau of Mines Central Experiment Station, Pittsburgh, Pennsylvania.

This report covers the work performed during the period from 1 November 1955 to 31 October 1956.

ABSTRACT

⌈The results of minimum spontaneous ignition temperature tests conducted on seven hydraulic fluids while in contact with seven surfaces found in aircraft under conditions likely to be encountered in practice are presented here. These tests were conducted by members of the Branch of Gas Explosions, Division of Explosives Technology, U. S. Bureau of Mines between 1 November 1955 and 31 October 1956. Hydraulic fluids Esso Univis J-43, conforming to specification MIL-O-5606, MLO 53-446 (General Electric GE 81406), MLO 54-540 (Monsanto OS 45), MLO 54-581, MLO 54-645 (85% Oronite 8200 + 15% Plexol), MLO 54-856 (Hollingshead 72073C), and MLO 8200 (Oronite 8200) were tested while in contact with heated aluminum, beryllium-copper, copper, magnesium, pyrex glass, stainless steel and titanium surfaces. The effects of both test chamber pressure and injection pressure variations were investigated.⌋

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

R. T. SCHWARTZ
Chief, Organic Materials Branch
Materials Laboratory
Directorate of Research

(57 pp) (18 fig.) (16 tbls..) (11 ref.)

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INTRODUCTION

The spontaneous ignition of a combustible in air has presented a safety problem for a number of years. As the temperatures of many components found in aircraft are elevated, the hazards associated with the spontaneous ignition of fuels, lubricants and hydraulic fluids will increase. Accordingly, it is of interest to determine the minimum spontaneous ignition temperatures of the combustibles used in aircraft when in contact with various typical surfaces as a function of ambient pressure and, in the case of hydraulic fluids, as a function of fluid pressure. From these data, one can then choose the safest hydraulic fluid for a particular application.

This work is a continuation of the program of research on the flammability characteristics of aircraft fuels and hydraulic fluids initiated at the U. S. Bureau of Mines in 1950. A summary of the work performed during the period February 1950 to October 1955 is given in WADC TR 52-35, Supplement 4, (Ref. 5, see also Ref. 1, 2). This report covers the unclassified work performed during the period 1 November 1955 to 31 October 1956. The classified work performed during the same period is presented in a separate report.

SECTION I

PURPOSE OF THE PROJECT

1.1 This project involves the determination of various flammability characteristics of seven hydraulic fluids while in contact with seven surface materials found in aircraft under conditions likely to be encountered in practice and of a high energy fuel in contact with two surface materials under the same conditions.

1.2 **Program**

1.2.1 The work to be conducted under Delivery Order AF 18(600)-151, Amendment 5(56-930) dated 9 January 1956 was grouped under the following headings:

Item XXIV: The following materials will be used in Phase I: MIL-O-5606 fluid, MLO 54-540, MLO 8200, MLO 54-645, MLO 53-446, and MLO 54-581 and other fluids as specified by the Materials Laboratory, Wright Air Development Center.

Item XXV: Determine the minimum spontaneous ignition temperature at 1, 0.5, and 0.25 atmosphere pressure of each of the fluids specified in Item XXIV as a function of injection pressure using a diesel injector and hollow-cone spray nozzle and a fixed nozzle-to-flask distance in conjunction with the I-8 Bureau of Mines Ignition Apparatus (Appendix II, WADC TR 52-35).

Item XXVI: Repeat. Item XXV using various metallic surfaces used in current aircraft, as specified by Materials Laboratory.

Item XXVII: Repeat. Items XXV and XXVI, but keeping the injection pressure constant and vary the nozzle-to-flask distance. Repeat for at least two additional injection pressures.

Item XXVIII: Determine the minimum spontaneous ignition temperatures in air of each of the fluids specified in Item XXIV, as a function of pressure between 0 and 3000 p.s.i.g. in a stainless steel vessel. Repeat with an adiabatic compression apparatus in which the air in contact with the hydraulic fluids is compressed adiabatically.

Item XXIX: Determine the limits of flammability of a high energy fuel, to be furnished by Materials Laboratory, over the temperature range -100° to +160°F. and the pressure range from 1 to 30 inches of mercury or these ranges extended if necessary. Determine the effect of the spark energy and electrode materials on the limits of ignitibility over the temperature and pressure ranges respectively. Determine the minimum Autogeneous Ignition Temperature at 2, 1.5, 1 and 1/2 atmosphere pressure in a static system. Determine ignition limits for HEF when varying percentages of inert gas (CO_2 and N_2) are introduced to form a three-phase gas system (air-inert gas-fuel vapor).

SECTION II

DEFINITIONS AND THEORY

2.1 The definitions and theory given in Section I, THEORY OF COMBUSTION, EXPLOSION AND IGNITION, of WADC TR 52-35, Supplement 4 (Ref. 5) are applicable to this report. Paragraph 1.3.1 of the above reference is of special interest here and is therefore repeated in part in the following paragraph.

2.2 If a combustible material is heated uniformly in an oxidizing atmosphere until a rapid self-sustaining combustion reaction occurs, the time lag between the onset of heating and the initiation of the above reaction is found to depend on a number of factors such as the temperature, pressure, volume, surface to volume ratio, mixture composition, sample injection velocity and composition of the heated surface. The effect of the surface may be minimized by using a combustion chamber made of fairly inert material and having a small surface to volume ratio. The ignition temperature data obtained in a particular apparatus may be used to determine the activation energy E for the oxidation process involved. This is done by using the statistical interpretation of the Arrhenius equation which takes the rate of a collisional reaction to be proportional to $\exp(-\frac{E}{RT})$. Since the rate of reaction is inversely proportional to the time of reaction we then have

$$\ln \Upsilon = \frac{E}{RT} + \text{constant}$$

where Υ is the time lag and T the absolute temperature. Therefore, a plot of $\ln \Upsilon$ against $\frac{1}{T}$ should give a straight line of slope E/R for any particular reaction. In practice, the reaction mechanisms are complex and vary with temperature so that a range of activation energies may be found for a range of temperatures (Ref. 3 and 4).

SECTION III

EXPERIMENTAL RESULTS

3.1 The results obtained from 1 November 1955 to 31 October 1956 are summarized in part in this unclassified report and in a second classified report.

3.2 Spontaneous Ignition:

3.2.1 The minimum spontaneous ignition temperatures of MIL-0-5606 fluid, MLO 53-446, MLO 54-540, MLO 54-581, MLO 54-645, MLO 54-856 and MLO 8200 were determined in air at one atmosphere pressure while in contact with aluminum, beryllium-copper, copper, magnesium, pyrex glass, stainless steel and titanium surfaces. The I-8 ignition temperature apparatus (see Figure 25, Ref. 1) was used for these determinations. The fluids were introduced into the heated test flasks made of the above materials with a hypodermic syringe (essentially zero p.s.i.g. injection pressure) or with a Bosch type T2 hollow cone diesel injector (150-5000 p.s.i.g. injection pressure). A summary of the data obtained is given in Tables 1-8, Appendix I, and presented graphically in Figures 1-9, Appendix II. Figure 1 gives the minimum spontaneous ignition temperatures of each of the above hydraulic fluids in contact with a pyrex glass surface at one atmosphere pressure as a function of diesel injector pressure. Figures 2-8 give the minimum spontaneous ignition temperatures at atmospheric pressure of MIL-0-5606, MLO 53-446, MLO 54-540, MLO 54-581, MLO 54-645, MLO 54-856 and MLO 8200, respectively, as a function of diesel injector pressure for each of the seven surfaces listed above.

3.2.2 Figures 1-8 show that of the seven fluids tested at one atmosphere pressure MIL-0-5606 fluid will ignite spontaneously in air at the lowest temperature and MLO 53-446 at the highest temperature when in contact with aluminum, beryllium-copper, copper, magnesium, pyrex glass, stainless steel or titanium surfaces. This is true regardless of the pressure used to project these fluids against the above heated surfaces. In general, as this injection pressure is increased, the surface temperature required to effect spontaneous ignition is decreased. Of the seven fluids tested, MLO 54-540 exhibited the greatest ignition temperature drop with increase in injection pressure. The minimum ignition temperature of this fluid in contact with pyrex at one atmosphere pressure dropped from 703°F. (373°C.) at zero injection pressure to 464°F. (204°C.) at 500 p.s.i. injection pressure; the distance between the injector and the pyrex surface was approximately 4 inches in these experiments.

3.2.3 The minimum spontaneous ignition temperatures of the above fluids were determined at reduced pressures when in contact with a pyrex glass surface. The fluids were introduced into the heated test flask with a

hypodermic syringe. A summary of the data obtained is given in Table 8, Appendix I, and presented graphically in Figure 9, Appendix II. Figure 9 shows that in general the ignition temperature of each of the fluids tested rises as the test pressure is decreased (i.e., as the altitude is increased). The notable exception here is MLO 53-446 which appears to have a constant minimum ignition temperature over the pressure range 1 to 1/2 atmosphere. The rate of increase of ignition temperature with decrease in pressure is greatest for MIL-O-5606 fluid. This rate of increase is such that this fluid has the highest minimum spontaneous ignition temperature at 1/4 atmosphere of any of the fluids tested at an essentially zero injection pressure. Accordingly, from the standpoint of safety from spontaneous ignition, MIL-O-5606 fluid appears to be the least desirable and MLO 53-446 the most desirable of the above hydraulic fluids for use at one atmosphere pressure in a low pressure hydraulic system. At 1/4 atmosphere MIL-O-5606 fluid appears to be the most desirable and MLO 53-446 the least desirable of the above hydraulic fluids in a low pressure system. A similar evaluation of these fluids for use in high pressure hydraulic systems must await the completion of high velocity fluid injection experiments at low chamber pressures. Such experiments are currently in progress.

3.3 Activation Energies

3.3.1 Activation energies were determined for the spontaneous ignition reactions involved in the above ignition temperature work. As expected, these energies were found to depend on the combustible, surface, temperature range, injection pressure, chamber pressure and fuel-air ratio. In general, they fell in the range 20 to 100 kcal/mole. For a given hydraulic fluid, surface, temperature range, chamber pressure and fuel-air ratio the activation energy generally decreased with increase in fluid injection pressure. This indicates that the conversion of the kinetic energy of the spray stream into heat may be one of the factors responsible for an ignition temperature lowering with increase in injection pressure. Additional work must be done on this subject before a more definite statement can be made, however.

SECTION IV

PROPOSED FUTURE INVESTIGATIONS

4.1 Tests conducted to date show the minimum spontaneous ignition temperature of a hydraulic fluid is dependent on the fluid injection pressure. Since the amount of this lowering appears to be quite important in some applications, the mechanism by which this lowering is achieved should be investigated. This can best be done by working with pure fluids instead of blends so that the effects of additives may then also be determined.

4.2 Spontaneous ignition temperature tests have been conducted on a number of combustibles at low pressures while in contact with various surfaces. This work should be extended to superatmospheric pressures for those combustible fluids that are to be used at elevated pressures.

4.3 Ignition temperature data should be obtained for a number of families of combustibles which may be used as fire resistant fluids or as additives to such fluids so that the effect of molecular structure on ignition temperature can be assessed. At present, such data are available on comparatively few combustibles.

SECTION V

CONCLUSIONS

5.1 The minimum spontaneous ignition temperatures of MIL-O-5606, MLO 54-540, MLO 54-645, MLO 54-581 and MLO 53-446 hydraulic fluids increase in the order noted while in contact with a pyrex surface at one atmosphere pressure and essentially zero p.s.i.g. injection pressure. Under the same conditions, the minimum spontaneous ignition temperatures of MLO 54-856 and MLO 8200 are the same as that of MLO 54-645. At 1/2-atmosphere pressure the minimum spontaneous ignition temperatures increase in the order MLO 53-446; MIL-O-5606 fluid; MLO 54-540; MLO 8200; MLO 54-645; MLO 54-856; MLO 54-581. At 1/4-atmosphere pressure the order becomes MLO 53-446; MLO 54-540; MLO 54-856; MLO 54-645; MLO 8200; MIL-O-5606 fluids; MLO 54-581. Thus, although MLO 53-446 is the best of the above fluids in terms of spontaneous ignition at atmospheric pressure, it appears to be the worst at pressures below 1/2 atmosphere.

5.2 The minimum spontaneous ignition temperatures of MLO 54-540, MLO 54-581, MLO 54-645, MLO 54-856 and MLO 8200 hydraulic fluids are decreased considerably when these fluids are injected into a heated surface at high velocity at one atmosphere pressure. There is very little change in the ignition temperatures of MIL-O-5606 fluid and MLO 53-446 under the same conditions. The reasons for this peculiar behavior in ignition temperatures are still uncertain.

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APPENDIX I

TABLES OF MINIMUM SPONTANEOUS IGNITION TEMPERATURES

Table 1.--Minimum spontaneous ignition temperatures (S.I.T.) and the corresponding time delays before ignition of MIL-O-5606 hydraulic fluid in air at one atmosphere test chamber pressure and various injection pressures.

Surface	Injection Pressure (p.s.i.g.)	S.I.T. °C.	°F.	Time delay before ignition (sec.)
Aluminum	0	226	439	245
	1000	230	446	156
	3000	228	442	157
	5000	230	446	160
Beryllium-Copper	0	226	439	299
	1000	230	446	124
	3000	230	446	110
	5000	230	446	110
Copper	0	232	450	193
	1000	230	446	153
	3000	230	446	120
	5000	230	446	97
Magnesium	0	230	446	207
	1000	230	446	115
	3000	230	446	109
	5000	230	446	83
Pyrex	0	225	437	253
	800-4500	226	439	198
Stainless Steel	0	228	442	225
	1000	230	446	120
	3000	230	446	120
	5000	230	446	120
Titanium	0	228	442	214
	1000	226	439	156
	3000	226	439	155
	5000	226	439	150

Table 2.—Minimum spontaneous ignition temperatures (S.I.T.) and the corresponding time delays before ignition of MLO-53-446 hydraulic fluid in air at one atmosphere test chamber pressure and various injection pressures.

Surface	Injection Pressure (p.s.i.g.)	S.I.T. °C.	°F.	Time delay before ignition (sec.)
Aluminum	0	424	795	54
	250	408	766	24
	500	404	759	21
	1000	396	745	29
	3000	396	745	40
	5000	396	745	34
Beryllium-Copper	0	402	756	53
	500	392	738	26
	1000	378	712	30
	3000	382	720	39
	5000	386	727	29
Copper	0	400	752	80
	500	392	738	24
	1000	386	727	18
	1500	386	727	37
	2000	390	734	26
	3000	390	734	20
	5000	384	723	30
Magnesium	0	406	763	63
	1000	406	763	17
	3000	406	763	20
	5000	406	763	17
Pyrex	0	419	786	40
	1000-5000	416	781	12
Stainless Steel	0	410	770	51
	500	396	745	29
	1000	392	738	36
	3000	392	738	47
	5000	392	738	38
Titanium	0	408	766	51
	500	398	748	28
	1000	392	738	34
	3000	396	745	41
	5000	396	745	39

Table 3.—Minimum spontaneous ignition temperatures (S.I.T.) and
the corresponding time delays before ignition of MLO-
54-540 hydraulic fluid in air at one atmosphere test
chamber pressure and various injection pressures.

Surface	Injection Pressure (p.s.i.g.)	S.I.T. °C.	°F.	Time delay before ignition (sec.)
Aluminum	0	322	612	7
	500	244	471	9
	1000	240	464	8
	3000	240	464	23
	5000	240	464	23
Beryllium-Copper	0	324	615	1
	500	244	471	3
	1000	240	464	6
	3000	240	464	14
	5000	240	464	15
Copper	0	324	615	5
	500	240	464	5
	1000	240	464	6
	3000	240	464	20
	5000	240	464	34
Magnesium	0	322	612	8
	500	248	478	3
	1000	240	464	9
	3000	240	464	16
	5000	240	464	14
Pyrex	0	373	703	6
	250	364	687	2
	300	336	637	1
	400	300	572	3
	500-4800	240	464	29
Stainless Steel	0	322	612	6
	500	240	464	4
	1000	240	464	7
	3000	240	464	10
	5000	240	464	20
Titanium	0	328	622	6
	500	244	471	3
	1000	244	471	5
	3000	240	464	19
	5000	240	464	15

Table 4.—Minimum spontaneous ignition temperatures (S.I.T.) and the corresponding time delays before ignition of MLO-54-581 hydraulic fluid in air at one atmosphere test chamber pressure and various injection pressures.

Surface	Injection Pressure (p.s.i.g.)	S.I.T. °C.	°F.	Time delay before ignition (sec.)
Aluminum	0	360	680	5
	500	294	561	6
	1000	286	547	7
	3000	270	518	61
	5000	270	518	93
Beryllium-Copper	0	342	648	10
	500	292	558	6
	1000	288	550	11
	2000	276	529	16
	3000	270	518	39
	5000	270	518	32
Copper	0	348	658	6
	500	292	558	6
	1000	292	558	7
	2000	286	547	10
	3000	276	529	31
	5000	266	511	56
Magnesium	0	370	698	6
	500	296	565	6
	1000	284	543	15
	3000	274	525	45
	5000	274	525	48
Pyrex	0	390	734	7
	250	386	727	2
	375	358	676	1
	500	300	572	5
	1000	290	554	12
	2000-7000	288	550	16
Stainless Steel	0	378	712	7
	500	288	550	6
	1000	288	550	4
	3000	264	507	25
	5000	260	500	14
Titanium	0	376	709	8
	500	306	583	4
	1000	288	550	4
	3000	268	514	30
	5000	268	514	62

Table 5.—Minimum spontaneous ignition temperatures (S.I.T.) and
the corresponding time delays before ignition of MLO-
54-645 hydraulic fluid in air at one atmosphere test
chamber pressure and various injection pressures.

Surface	Injection Pressure (p.s.i.g.)	S.I.T. °C.	°F.	Time delay before ignition (sec.)
Aluminum	0	362	684	7
	500	268	514	9
	1000	264	507	5
	3000	260	500	8
	5000	256	493	13
Beryllium-Copper	0	360	680	7
	500	268	514	12
	1000	268	514	9
	3000	264	507	7
	5000	260	500	11
Copper	0	354	669	6
	500	263	514	7
	1000	264	507	6
	3000	260	500	6
	5000	264	507	6
Magnesium	0	356	673	6
	500	268	514	9
	1000	264	507	10
	3000	264	507	6
	5000	260	500	11
Pyrex	0	380	716	10
	150	374	705	1
	350	298	568	2
	500	274	525	5
	750	262	504	6
	1000-5000	258	496	8
Stainless Steel	0	364	687	10
	500	268	514	9
	1000	264	507	7
	3000	260	500	6
	5000	256	493	17
Titanium	0	364	687	7
	500	268	514	6
	1000	264	507	5
	3000	264	507	7
	5000	260	500	10

Table 6.—Minimum spontaneous ignition temperatures (S.I.T.) and the corresponding time delays before ignition of MLO-54-856 hydraulic fluid in air at one atmosphere test chamber pressure and various injection pressures.

Surface	Injection Pressure (p.s.i.g.)	S.I.T. °C.	°F.	Time delay before ignition (sec.)
Aluminum	0	356	673	7
	500	288	550	15
	1000	284	543	22
	3000	268	514	38
	5000	268	514	65
Beryllium-Copper	0	356	673	5
	500	288	550	13
	1000	288	550	18
	3000	276	529	29
	5000	268	514	33
Copper	0	360	680	6
	500	288	550	9
	1000	288	550	16
	2000	284	543	7
	3000	270	518	39
	5000	274	525	37
Magnesium	0	356	673	9
	500	288	550	10
	1000	284	543	16
	3000	272	521	45
	5000	268	514	40
Pyrex	0	380	716	7
	175	290	554	8
	250-5000	282	540	10
Stainless Steel	0	356	673	8
	500	280	536	21
	1000	276	529	9
	3000	276	529	21
	5000	276	529	13
Titanium	0	368	694	8
	500	284	543	9
	1000	280	536	9
	3000	268	514	20
	5000	264	507	48

Table 7.—Minimum spontaneous ignition temperatures (S.I.T.) and the corresponding time delays before ignition of MLO 8200 hydraulic fluid in air at one atmosphere test chamber pressure and various injection pressures.

Surface	Injection Pressure (p.s.i.g.)	S.I.T. °C.	°F.	Time delay before ignition (sec.)
Aluminum	0	356	673	7
	500	260	500	8
	1000	260	500	7
	3000	256	493	16
	5000	248	478	22
Beryllium-Copper	0	358	676	4
	500	268	514	8
	1000	264	507	7
	3000	256	493	13
	5000	256	493	16
Copper	0	362	684	5
	500	268	514	6
	1000	260	514	8
	3000	252	486	13
	5000	256	493	12
Magnesium	0	358	676	9
	500	264	507	8
	1000	260	500	7
	3000	256	493	15
	5000	256	493	22
Pyrex	0	380	716	6
	175	368	694	1
	250	310	590	1
	500	282	540	2
	1000-4800	264	507	8
Stainless Steel	0	356	673	5
	500	264	507	8
	1000	256	493	8
	3000	256	493	13
	5000	256	493	13
Titanium	0	362	685	7
	500	264	507	7
	1000	264	507	7
	3000	256	493	16
	5000	256	493	17

Table 8.--**Minimum spontaneous ignition temperatures (S.I.T.) and the corresponding time delays before ignition of seven hydraulic fluids in air while in contact with a pyrex surface at each of three test chamber pressures.**

Hydraulic Fluid	Pressure	S.I.T. °C.	S.I.T. °F.	Time delay before ignition (sec.)
MIL-O-5606	1/4 atm.	556	1033	4
	1/2 "	438	820	3
	1 "	225	437	253
MLO 53-446	1/4 atm.	442	828	14
	1/2 "	424	795	38
	1 "	419	786	40
MLO 54-540	1/4 atm.	510	950	9
	1/2 "	448	838	3
	1 "	373	703	6
MLO 54-581	1/4 atm.	548	1036	5
	1/2 "	480	896	4
	1 "	390	734	7
MLO 54-645	1/4 atm.	520	968	7
	1/2 "	452	846	2
	1 "	380	716	10
MLO 54-856	1/4 atm.	516	961	9
	1/2 "	460	860	11
	1 "	380	716	7
MLO 8200	1/4 atm.	522	972	5
	1/2 "	450	842	3
	1 "	380	716	7

APPENDIX II

FIGURES
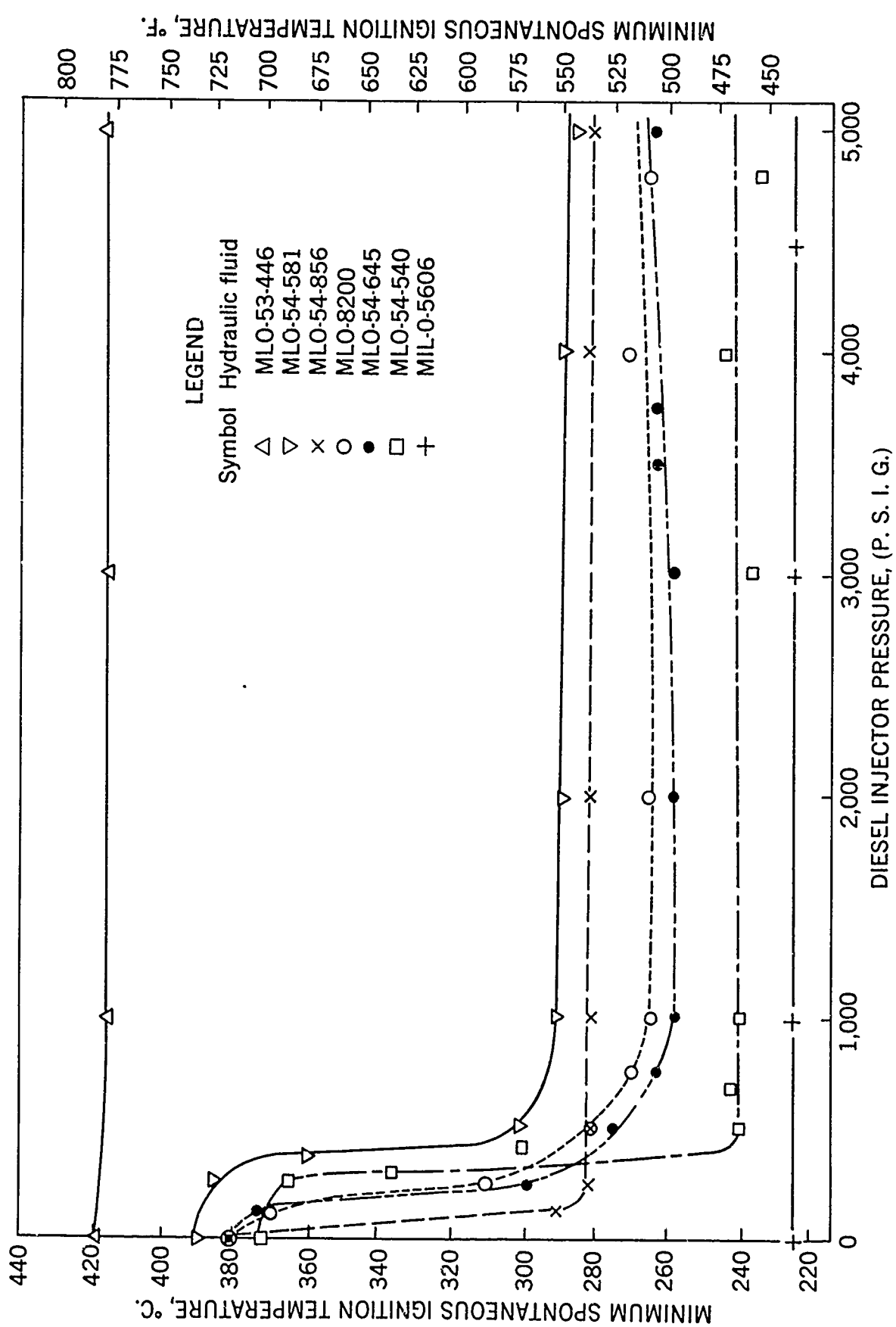
Figure 1. Minimum spontaneous ignition temperatures of seven hydraulic fluids in air at one atmosphere pressure in contact with a pyrex glass surface as a function of diesel injector pressure.
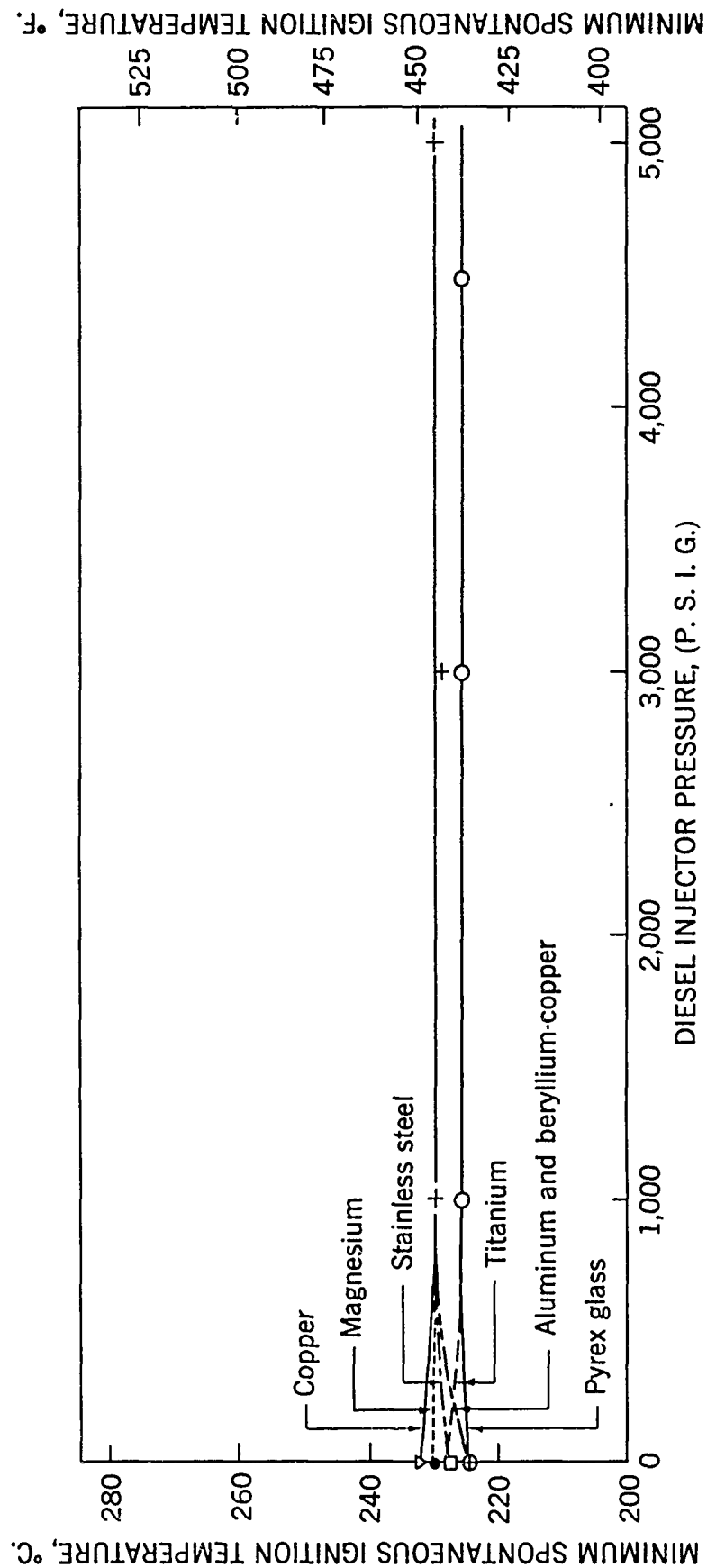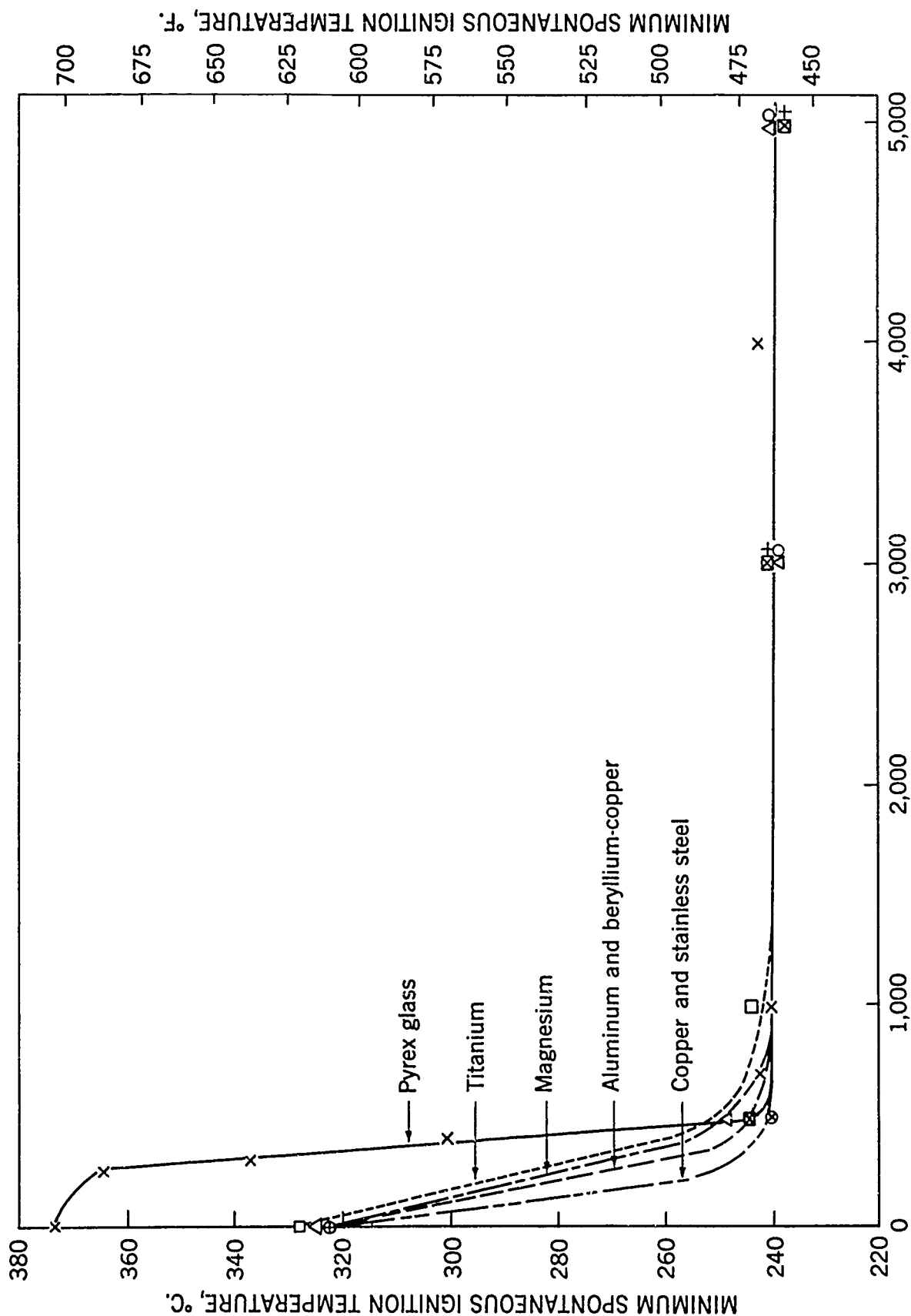
Figure 2. Minimum spontaneous ignition temperatures of MIL-O-5606 hydraulic fluid in air at one atmosphere pressure in contact with various surfaces as a function of diesel injector pressure.
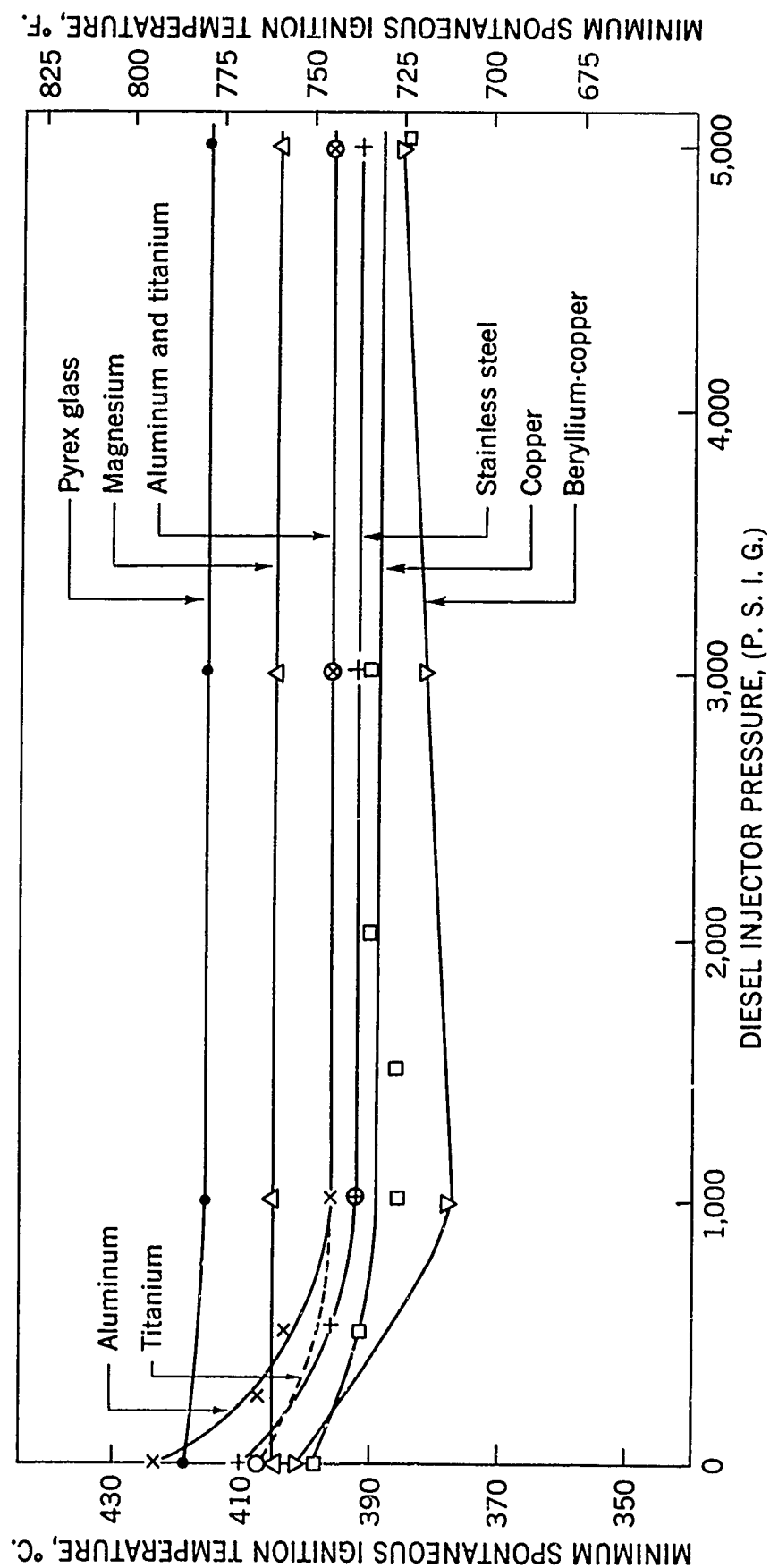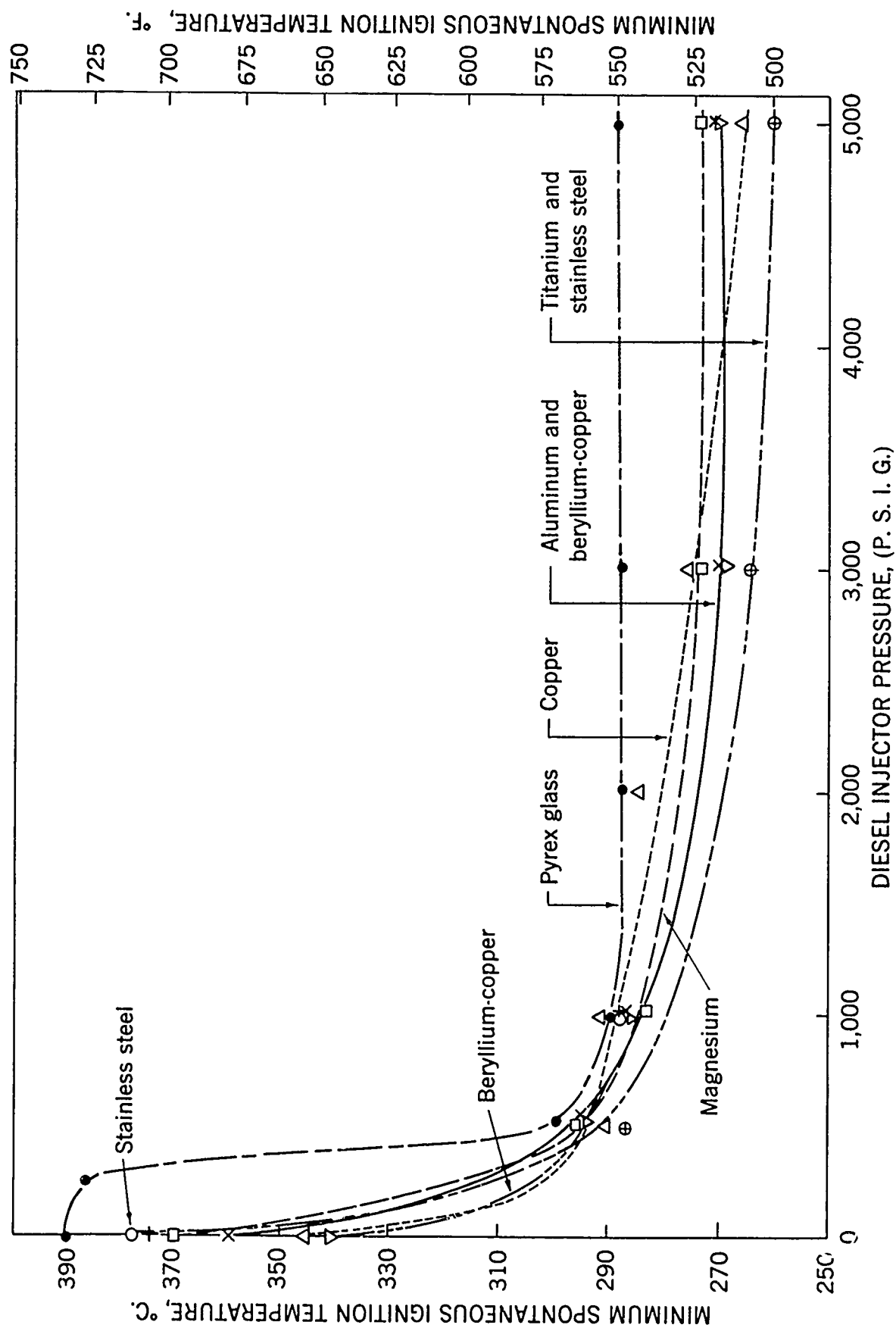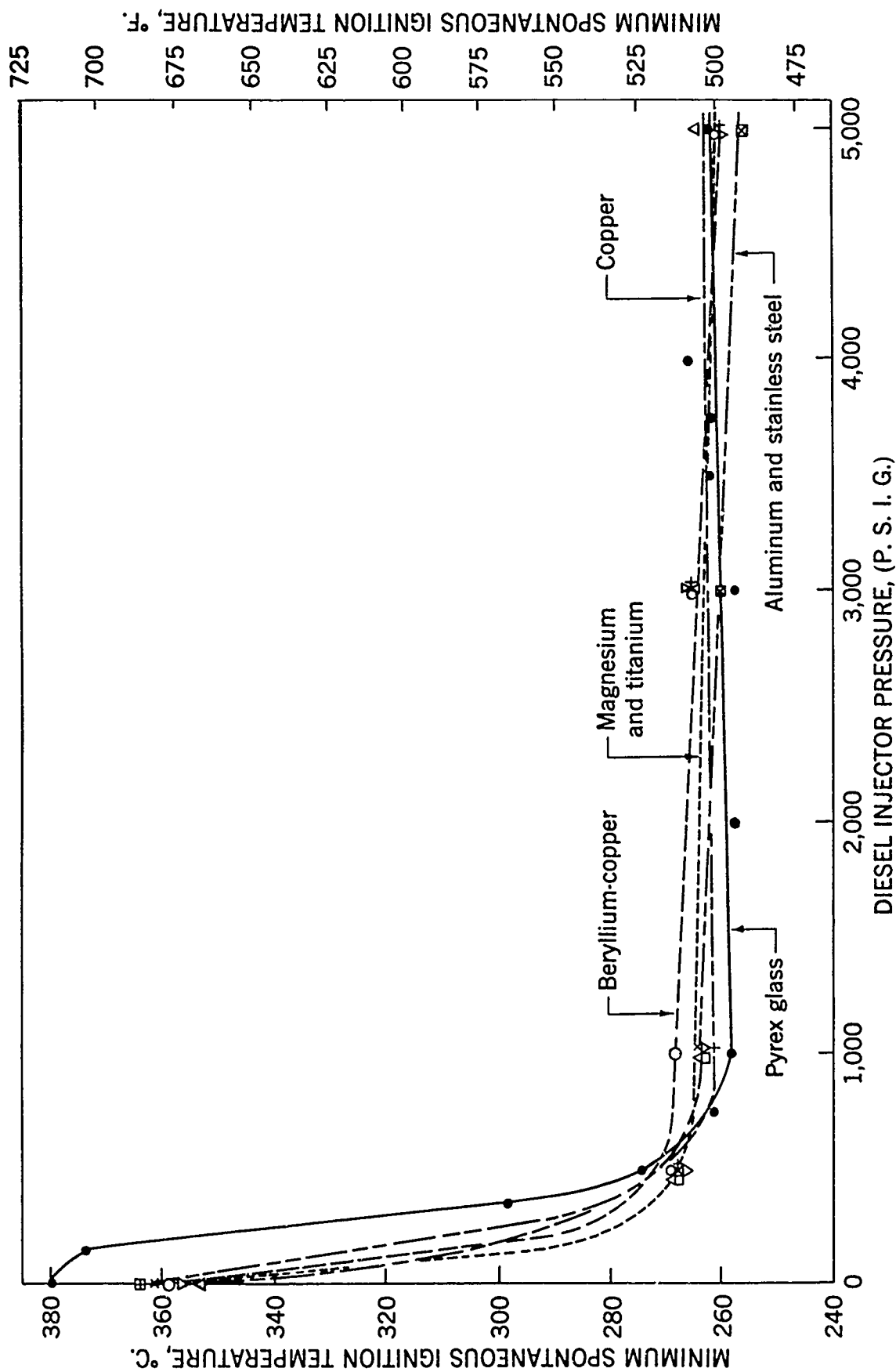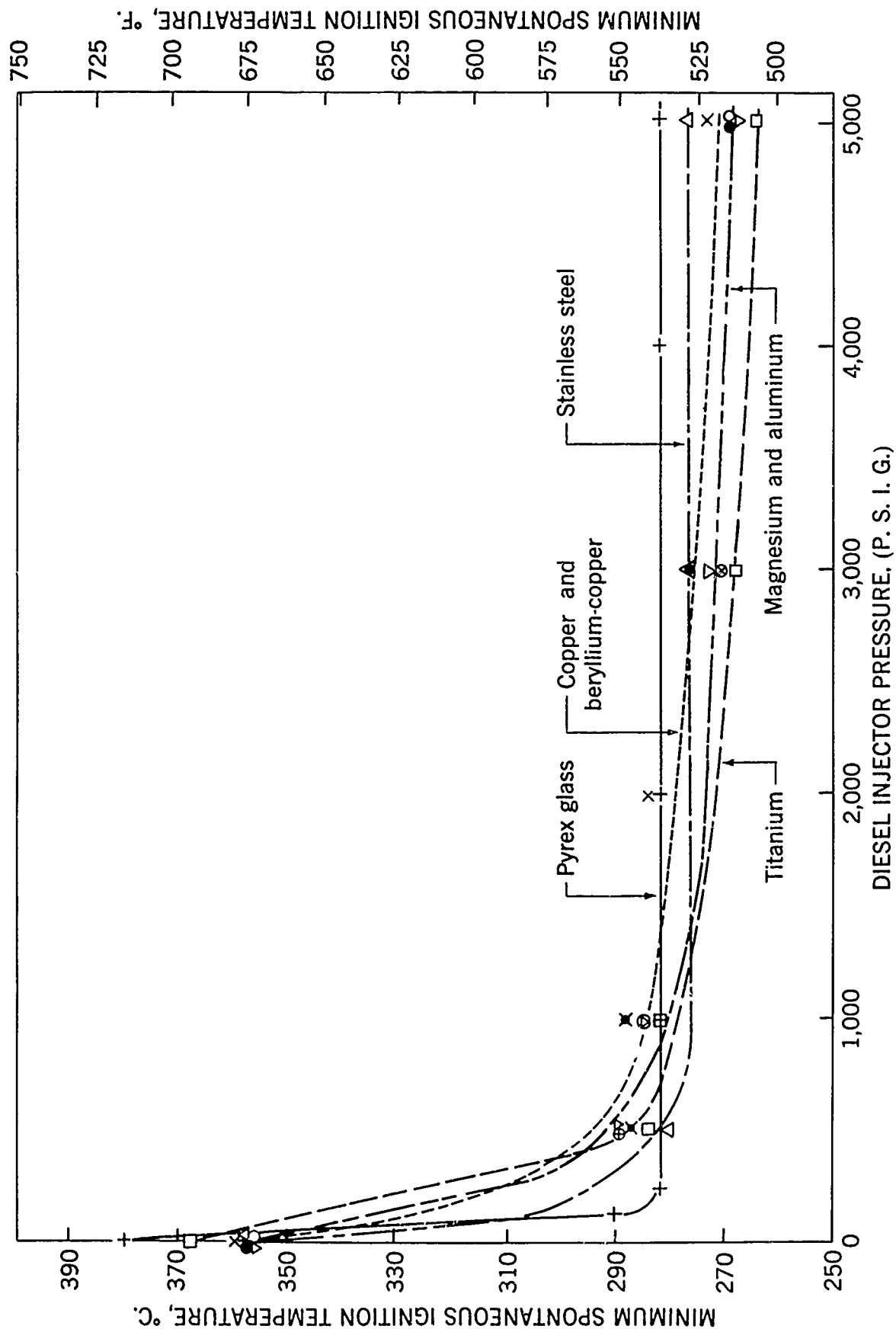
Figure 3. Minimum spontaneous ignition temperatures of MLO 53-446 hydraulic fluid in air at one atmosphere pressure in contact with various surfaces as a function of diesel injector pressure.

Figure 4. Minimum spontaneous ignition temperatures of MLO 54-540 hydraulic fluid in air at one atmosphere pressure in contact with various surfaces as a function of diesel injector pressure.
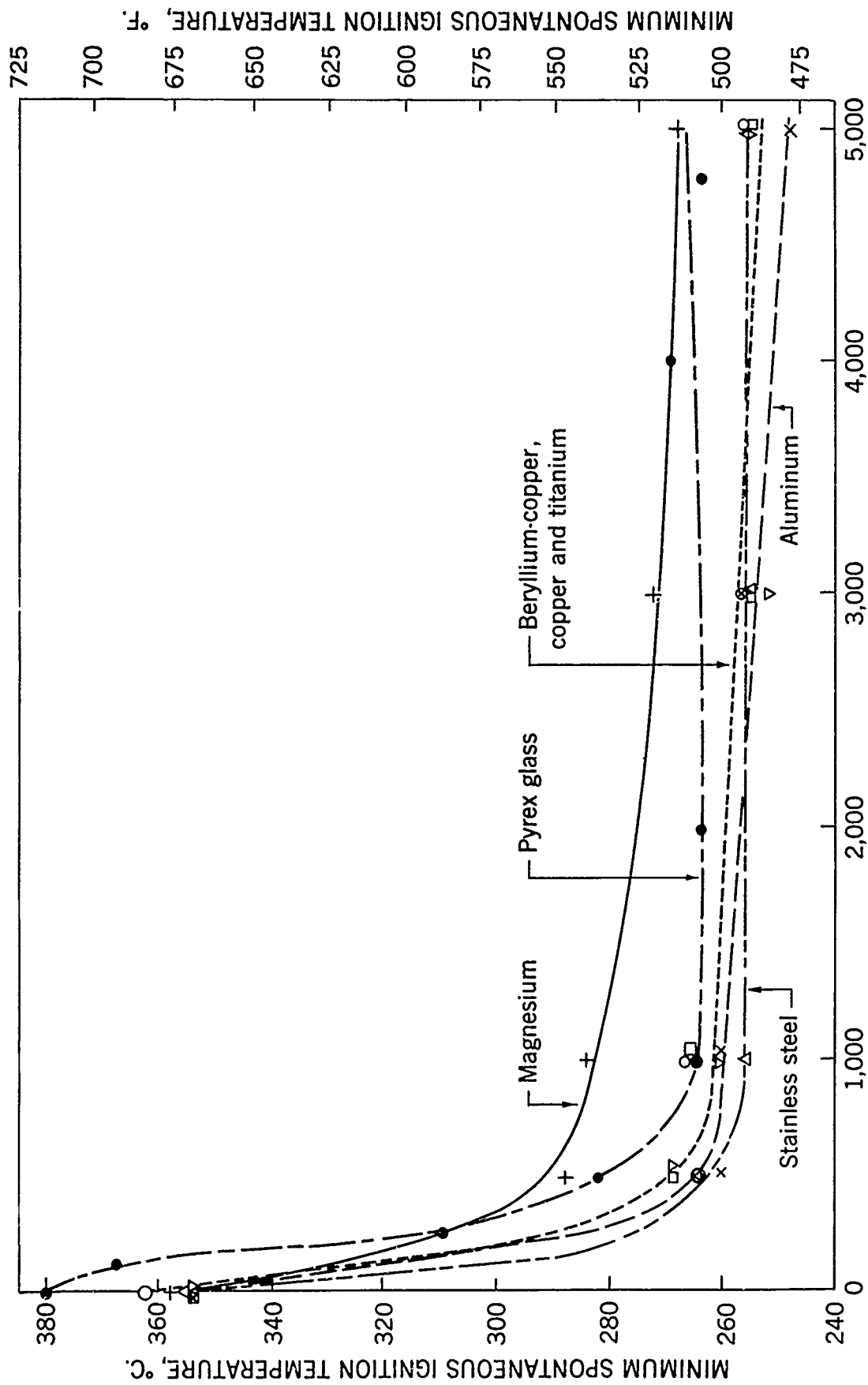
Figure 5. Minimum spontaneous ignition temperatures of MLO 54-581 hydraulic fluid in air at one atmosphere pressure in contact with various surfaces as a function of diesel injector pressure.
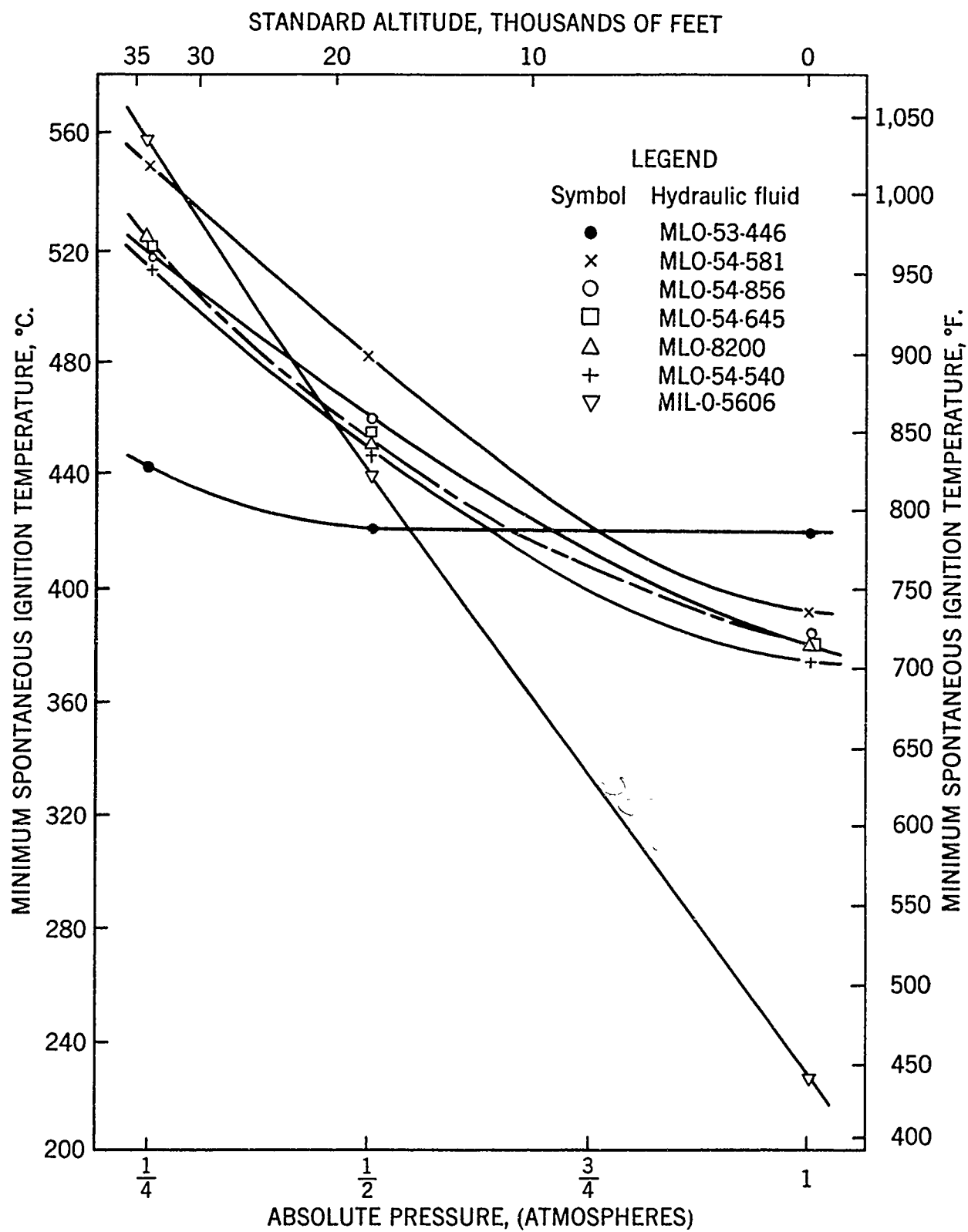
Figure 6. Minimum spontaneous ignition temperatures of MLO 54-645 hydraulic fluid in air at one atmosphere pressure in contact with various surfaces as a function of diesel injector pressure.

Figure 7. Minimum spontaneous ignition temperatures of MLO 54-856 hydraulic fluid in air at one atmosphere pressure in contact with various surfaces as a function of diesel injector pressure.

Figure 8. Minimum spontaneous ignition temperatures of MLO 8200 hydraulic fluid in air at one atmosphere pressure in contact with various surfaces as a function of diesel injector pressure.

Figure 9. Minimum spontaneous ignition temperatures of seven hydraulic
fluids in air in contact with a pyrex glass surface as a
function of test chamber pressure.

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